Interferometric Range Transceiver for Measuring Temporal Gravity Variations

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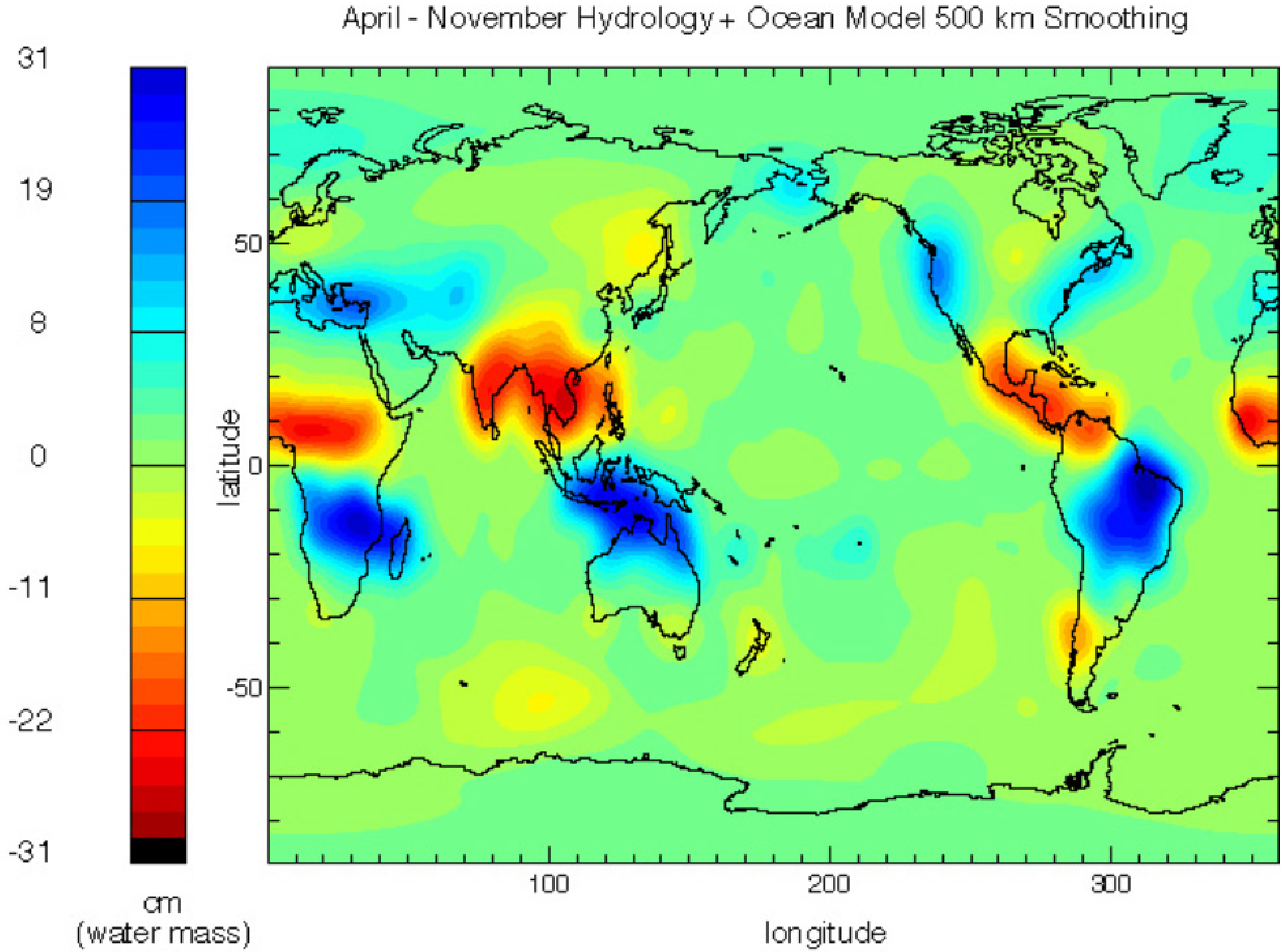
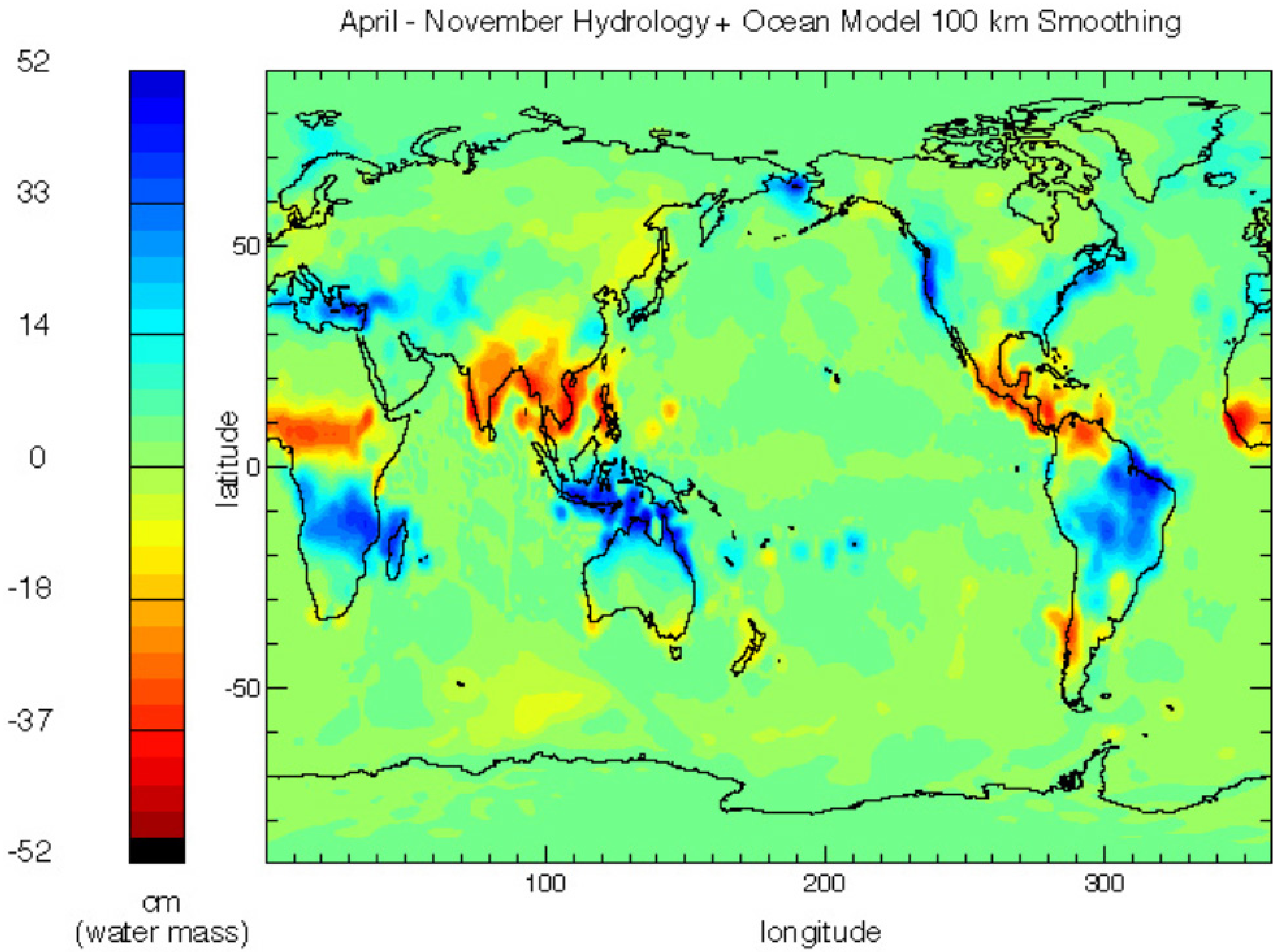
GRACE and a GRACE follow-on mission

- **GRACE provides monthly estimates of the Earth's time-varying gravity field**
  - **Uses microwave ranging, precision accelerometers, GPS navigation**
  - **Contributions to oceanography, hydrology, glaciology, solid earth sciences and geodesy**
- **A GRACE follow-on could provide a factor of 5 improvement in spatial resolution for 1 cm water accuracy**
  - **Proposed mission uses precision accelerometer and drag-free disturbance reduction system**
  - **Space Technology 7 (ST7) technology**
  - **Uses interferometric laser ranging system to improve ranging precision**

What GRACE can observe



What GRACE follow-on might observe



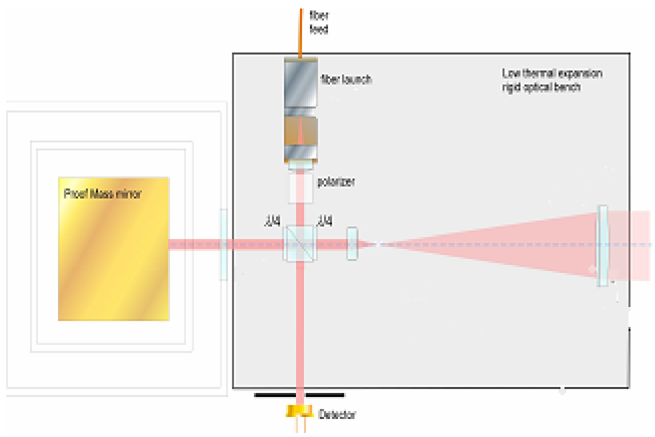
What are we trying to accomplish?

- **The goal of this instrument incubator investigation is to develop a laboratory demonstration of a laser interferometric ranging system suitable for a GRACE Follow-On mission.**
  - **Demonstrate a ranging measurement with 1 nm/⌧Hz displacement sensitivity from 0.01 to 0.1 Hz**
  - **Demonstrate capability for pointing acquisition**
- **This work will include verifying the performance of the system relative to the science requirements, and environmental testing of the system sufficient for a rating of TRL 6.**
- **In addition, the performance of the system for recovering the gravity field will be ascertained through simulations using the instrument error budget and assumptions about the mission design.**

What we are not doing

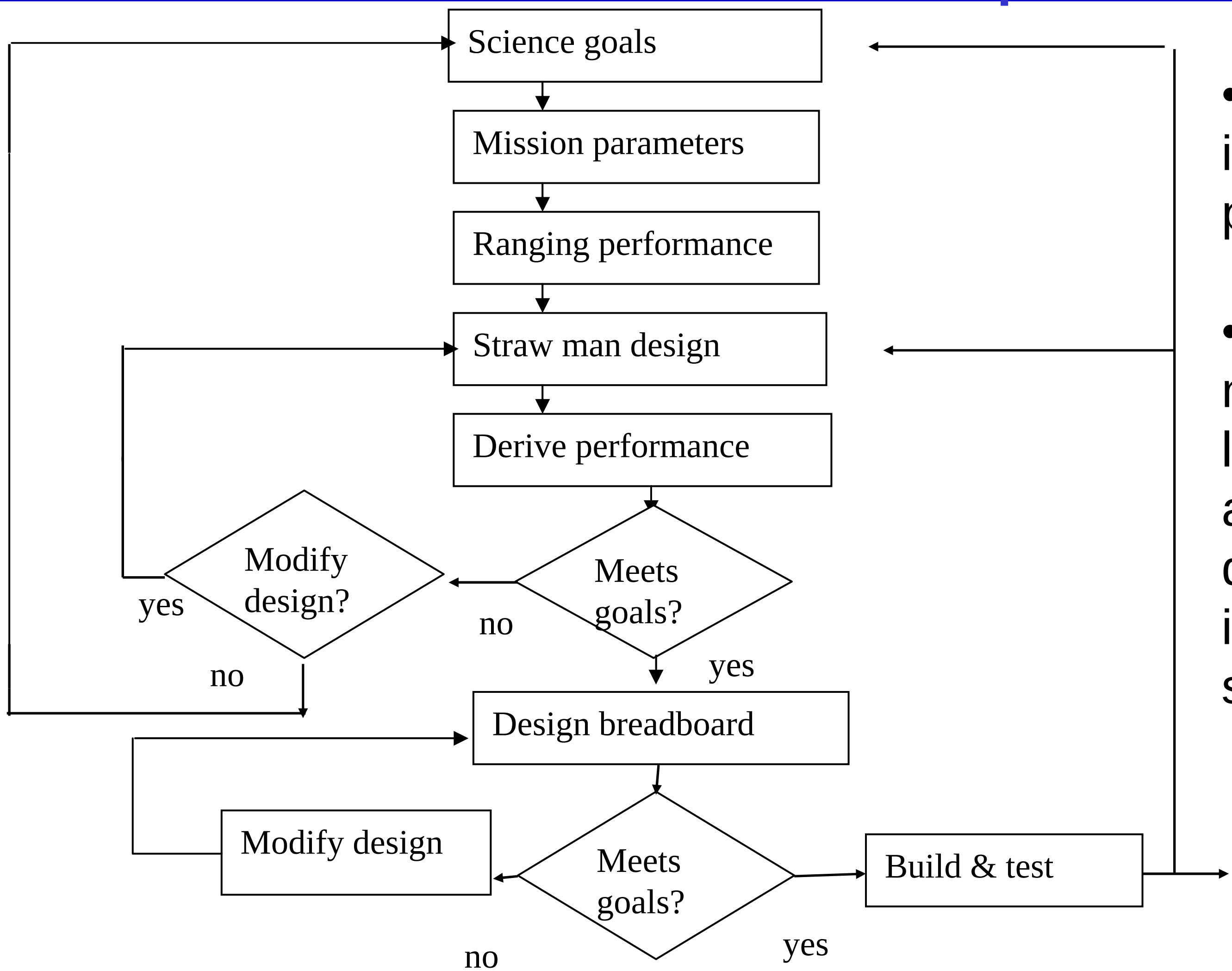
- We are not performing mission or spacecraft design for the next GRACE mission (though we are adopting some reasonable mission parameters needed for our instrument design)
- We are not developing the Gravitational Reference Sensor (GRS) (though we are using simulated proof-masses in our interferometer breadboard design).
- We are not developing techniques for drag-free operations using micro-thrusters.
- We are not developing improved methods for laser frequency stabilization (cavity vs. iodine, etc.).

We are working with a strawman interferometer design



- Simple heterodyne interferometer
  - Extremely simplified version of design for Laser Interferometer Space Antenna (LISA)
- Spacecraft pointing signal derived from quadrant photodiode at output of interferometer
- 2 spacecraft separated by 50 km
- The laser on spacecraft 2 is phase-locked with an offset frequency to the laser on spacecraft 1

The flight design error budget guides the interferometer design and laboratory test plans



- This the first step in an iterative process
- Early stage of mission design has led to many assumptions, definition of interfaces to other subsystems

Understand, control, and reduce all error terms within the interferometer

- GRS acceleration noise and laser frequency noise are outside the program scope
  - GRS advancements through ST7, LISA, GRACE
  - Currently no funded efforts to develop stabilized lasers
- Other important error sources are
  - Pointing jitter and wavefront distortion coupling
  - Phase measurement noise
  - Phase-lock clock noise
  - Temperature fluctuations

Key features of first year breadboard

- Two commercial NPRO lasers
  - One laser is master, the other is offset-locked to it
  - No additional frequency stabilization, 5 kHz linewidth
- Two flat mirrors to simulate proof masses of accelerometers
- One proof mass can actively rotate at μradian level
- Independent length monitor
- Blackjack phasemeter
  - Provided by JPL
- Initially in air, later in vacuum

What we will do ….

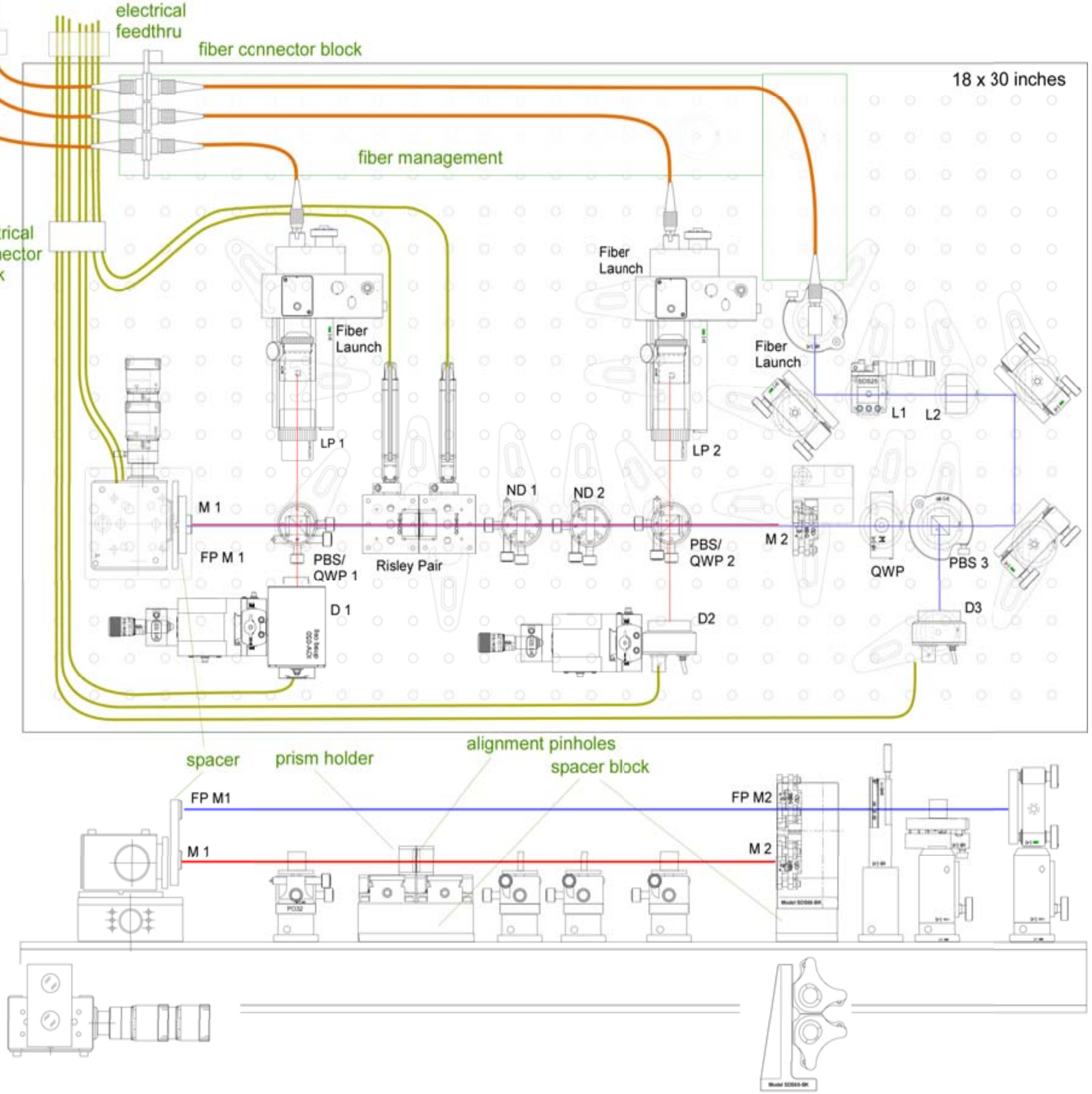
- Validate system-level performance
- Demonstrate phase measurement in presence of Doppler shift
- Demonstrate integrity of spacecraft pointing signal
- Verify pointing acquisition range
- Validate error budget contribution of
  - Clock noise
  - Laser frequency noise
- Test thermal stability (on component level)
- Identify unexpected error signals
- Validate test methodology for future work

What we won't do….

- Include telescope
- Wavefront distortion- pointing jitter
- Sunlight simulation
- Pointing acquisition range with flight-like telescope

Current status

- **Ordering parts**
- **Assembling breadboard**
- **Subsystem-level tests**



Plans for future work

- Results from breadboard October 2004
- Re-design for flight-like instrument
- Test interferometer system in relevant space environment
- TRL 6 by October 2006